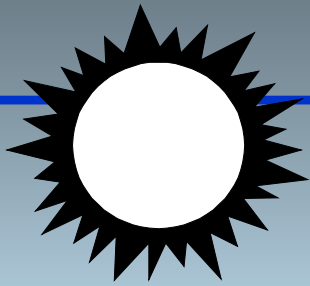


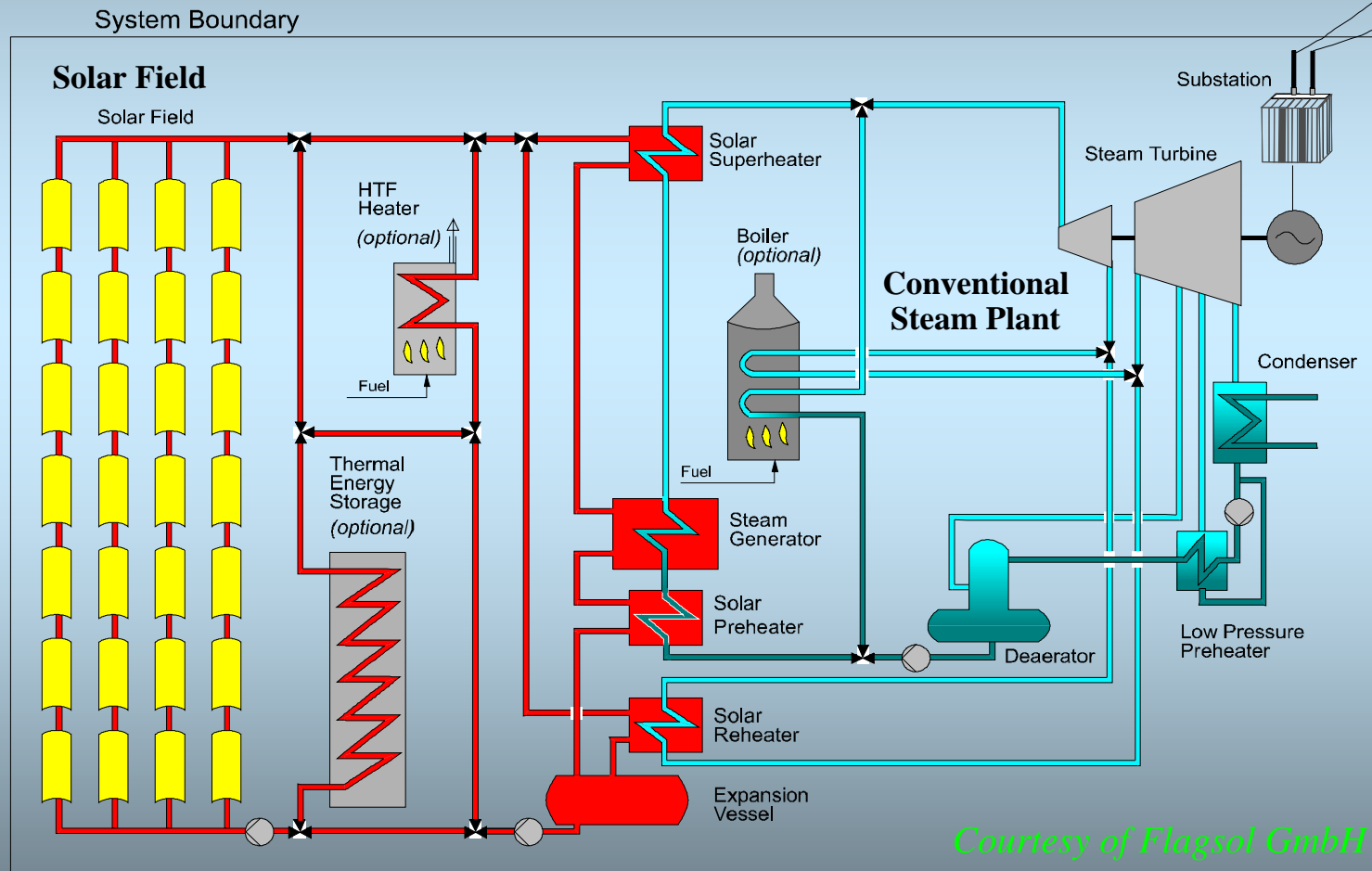


**ASSESSMENT OF THERMAL ENERGY STORAGE
FOR
PARABOLIC TROUGH SOLAR POWER PLANTS**

Solar Electric Generating System Rankine Cycle



Sunlight:
 $2,7 \text{ MWh/m}^2/\text{yr}$

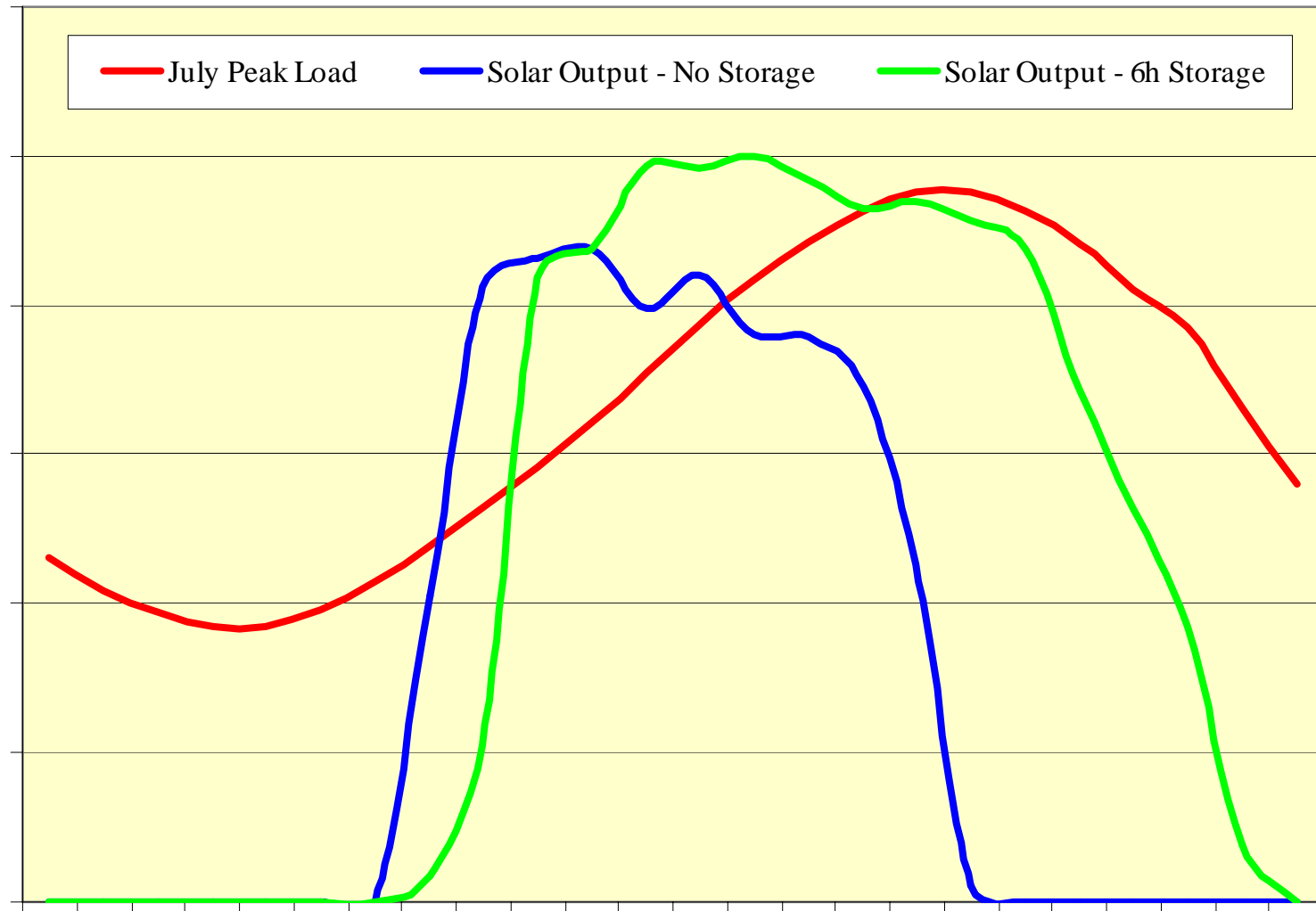


Need and Status

- Thermal storage provides a measure of dispatchability to trough plant electrical generation
- Storage provides boost in solar-only capacity factor w/o use of fossil fuel
- Solar field energy output (~ 400 C) is stored and used at a later time
- Storage capacities from 3-12 equivalent full load hours have been evaluated
- Commercial systems are in development*, but costs must be reduced in future designs

* 2 50-MWe trough plants in Spain with 7 hrs 2-tank molten salt system

SoCal Muni – Peak Load Day and Solar Output



Trough Thermal Energy Storage

Technology R&D

Near-term Option

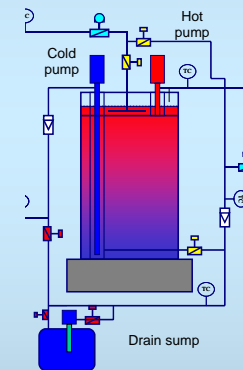
- **Two Tank Molten Salt Storage**
 - ◆ Leveraged experience from Solar Two's TES.
 - ◆ Heat transferred via an oil-to-salt HX.

Advanced Technologies

- **Thermocline Molten Salt System**
 - ◆ Single tank. Hot and cold separated with thermal gradient.
 - ◆ Low-cost filler material
 - ◆ Design and operation more complex than 2-tank
- **Molten Salt HTF/Storage**
 - ◆ Increased operating temperature (450-500C), reduced piping cost, reduced parasitics
 - ◆ Freeze protection of fluid (120C), SCA interconnection, increased O&M complexity
- **Advanced HTF**
 - ◆ Organic salts have potential to be thermally stable to above 400 C with very low freezing point
 - ◆ Compatible with alloys used in solar plants, non-flammable, low vapor pressure
 - ◆ Cost and temperature stability issues



Solar Two Molten Salt Thermal Storage



Prototype Thermocline Storage



Imidazolium Salt

Exergy Modeling

- Comparison of several thermal energy storage methods for troughs
 - ◆ Indirect systems with oil HTF in the solar field interfacing with 2-tank molten salt storage (like AndaSol)
 - ◆ Direct systems with molten salt in solar field and TES system. Parameters of:
 - ◆ Salt constituents and temperature level
 - ◆ 2-tank or thermocline TES system
 - ◆ TES system capacity

Parametric variations

- type of storage system – indirect or direct
- configuration of the storage system – two-tank or thermocline
- solar field HTF media – Therminol VP-1 or molten salt
- storage system media – molten salt type or molten salt/filler material type
- maximum working temperature of the storage system
- storage system design capacity in terms of full load electrical generation hours.

Estimated TES Costs

3600 MWh_t two-tank/thermocline (approximately 12 hours of TES for 100MWe Plant)

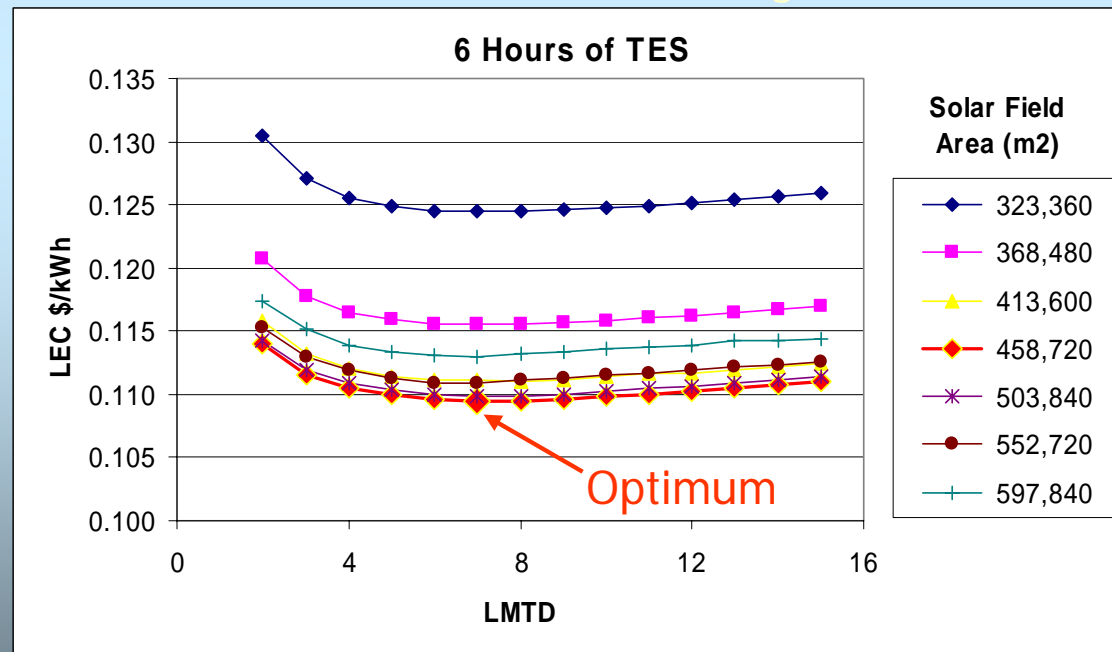
	Indirect Storage System	Direct Storage Systems	
Component	Two-Tank	Two-Tank	Thermocline
Solar Field HTF, type Outlet Temperature (°C)	Therminol 391 (736°F)	HitecXL 450 (842°F)	HitecXL 450 (842°F)
Storage Fluid, type Fluid cost, (k USD)	Solar Salt 51,200	HitecXL 71,200	HitecXL 26,000
Filler material, type Filler cost, (k USD)	NA 0	NA 0	Quartzite 8,700
Tank(s), number Tank cost, (k USD)	3 Hot, 3 Cold 23,400	2 Hot, 2 Cold 18,200	2 Thermocline 12,100
Salt-to-oil heat exchanger, (k USD)	9,000	0	0
Piping/Solar Field Heat Tracing	0	10,600	10,600
Total, (k USD)	91,900	108,900	62,000
Specific cost, (USD/kWh _t)	26	33	19
Development status	early commercial	pre-feasibility study	pre-feasibility study

Near-Term Thermal Energy Storage

Design Optimization

- ◆ Design optimization study to minimize cost
- ◆ Sizes considered 2, 4, 6, 9, and 12 hours of TES
- ◆ Optimized heat exchanger size

Near-Term 50 MWe Trough Plant



Thermal Storage Technology

Impact on Cost of Energy

Enabling Technologies

- Salt HTF
- Thermocline Storage

Near-Term 50 MWe Trough Plant

